

STRENGTH OF MATERIALS

Torsion Laboratory

Objective:

The purpose of this exercise is to verify experimentally the accuracy of the torque angular displacement relationship and to demonstrate the effect of cross sectional geometry in round members subjected to torsion.

Theory:

The torque-angular displacement relationship for a uniform circular member is given by:

$$\theta = \frac{TL}{JG} \quad (1)$$

where T is the applied torque (in-lb)

L is the length between torque application points (in)

G is the modulus of rigidity or shear modulus (lb/in²)

J is the polar moment of inertia (in⁴)

θ is the angle of twist (radians).

To evaluate the accuracy of equation (1), an experimental J value will be found according to the relationship in the form of:

$$J = \frac{T}{\theta} \left(\frac{L}{G} \right) = K \left(\frac{L}{G} \right) \quad (2)$$

where $K=T/\theta$ is the slope of a torque-angular displacement graph. Torsional stiffness expressed by the equation $K = T/\theta$ is defined as the torque required to produce a unit angle of rotation. From the equation, it is observed that K is directly proportional to J and inversely proportional to L.

Comparison of the experimental J value can then be made with the theoretical J value obtained from the equation:

$$J = \frac{\pi}{32} (r_o^4 - r_i^4) = \frac{\pi}{32} (d_o^4 - d_i^4) \quad (3)$$

where $r_i = d_i/2 = 0$ for a solid rod.

Effect of Cross-Sectional Geometry:

The torsion test will be performed using two rods made of the same material with different cross-sectional geometry. Comparison of the results will serve to demonstrate the effect of a solid versus hollow geometry in round members subjected to torsion. Each rod is composed of brass with a modulus of rigidity (G) of 5.2×10^6 psi.

Procedure:

1. Measure the outer diameter of each specimen (the wall thickness of the hollow tube is 0.025 in.). Two plexiglass protractors with scales in degrees are attached to the specimen at B and C (Figure 1). The length of the test section between B and C should be measured, as well the length of the loading lever arm. Record the data in Table 1.

2. For each specimen, place the loads in the weight pan at 1-lb increments and record the corresponding angle of twist in degrees at protractors B and C for each increment (Table 2).
3. Calculate the torques, the angular displacement between B and C and convert degrees to radians to complete Table 3.
4. Using a spreadsheet/graphing program, plot a single graph of torque (in-lb) versus angular displacement (radians) for both the solid rod and the hollow tube. Use a scatter plot to show the experimental data points.
5. Calculate the slope of each set of data using a least squares fit, show the lines on the graph and indicate the slope values. (A two-point or estimated slope will not be accepted.)
6. Calculate the theoretical J using Eq. 3 and the experimental J using the slopes obtained above. Compare the two values of J and determine the percent difference to complete Table 4.
7. Complete Table 5.

Report:

Your laboratory report should be in the format specified by your instructor and include the graphs and calculations described above as well as all data tables. A discussion of the observed effects of cross sectional area and geometry must be included using the data in Table 5. Why are hollow shafts often observed in the fleet?

Table 1 – Geometric Data

	Solid rod	Hollow rod
Apparatus number		
Specimen length B-C (in)		
Specimen diameter (in)		
Loading lever arm (in)		

Table 2 – Observed Data

	Angular displacement - solid rod		Angular displacement - hollow rod	
Load (lbs)	Protractor B (deg)	Protractor C (deg)	Protractor B (deg)	Protractor C (deg)

Table 3 - Computed Data

Torque (in-lb)	θ Solid rod B-C (rad)	θ Hollow rod B-C (rad)

Table 4 – Comparison of Experimental and Theoretical Values of J

	Solid Rod	Hollow Rod
J experimental (in ⁴)		
J theoretical (in ⁴)		
% Difference		

Table 5 - Effect of Geometry

	Solid Rod	Hollow Rod
Cross sectional area (in ²)		
Torsional stiffness (in-lb/rad)		

